Wood Decay

by
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A new concept about how decay begins and develops in wood has emerged in recent years. The decay process is no longer seen as a simple relationship between wood and fungi, but as a complex succession of events that involve chemical reactions, bacteria, different kinds of fungi, and discoloration. Research on this new concept has revealed the unique ways in which a tree reacts to its wounds by sealing off the affected tissues. Even though a tree may be rotten at the core, it may still live on to produce healthy new wood for a long time.

Natural process. Decay of wood is a natural and dynamic process. If wood and other organic matter did not decay, the Earth would soon be covered with dead matter, oxygen would not be released, and the Earth would lack other materials essential for life.

No doubt decay has been known ever since humans first began to climb trees and to use wood for tools and shelter and fuel. And today decay of living trees and wood products is still a problem of worldwide dimensions. Decay causes more damage to trees—and loss of wood fiber—all over the world than all the other destructive forces combined; it is a threat to every product made of wood.

The causes of decay were not understood until the late 1800s. Before that time, it was thought that decay caused fungi. Then Robert Hartig, a German plant pathologist and forester, advanced the theory that it was the other way around: fungi cause decay. Hartig's research set the foundation for the science of forest pathology.

Hartig developed his concept of decay around three major events: a wound, infection of the wound by decay fungi, and breakdown of the wood by the fungi. This classical concept remained essentially unchanged until a few years ago. Now, results of recent research have made it necessary to reexamine and expand upon Hartig's original concept.

Starting point. As in Hartig's concept, the wound is still the starting point (Fig. 1). But it is now known that a complex succession of events takes place in the processes that lead to decay. In living trees, discoloration of the wood usually precedes decay; therefore decay cannot be considered without considering discoloration (Fig. 2).

Wounds that may start the decay process can occur in many ways. A branch may die or break off; insects, birds, or animals may wound the tree; a fire may burn the base; snow or ice may break limbs; frost may crack the stem; or a logging machine may scrape the tree in passing.

When the tree is wounded, some living cells may be killed and others may be injured. The injured cells are exposed to the air. Chemical changes quickly take place in the wood. Phenolic substances in the cells are quickly oxidized. The oxidized phenols then begin to polymerize. Polyphenoloxidase enzyme systems are activated after wounding. Slight discoloration of the wood results, owing to the dark materials formed in the living wood cells by the chemical changes. Sometimes the early discoloration is a bleaching of the wood rather than a darkening. Vessel plugging is associated with the bleaching. The materials that plug the vessels come from the living cells that surround the vessels. Some of these parenchyma cells are in contact with the ray parenchyma and the vessels. These "contact cells" are thought to be the principal regulators of changes that take place after wounding. The intense activity of the "contact cells" can be demonstrated by the use of nitroblue tetrazolium.

Fig. 1. Severe wound on yellow birch tree 106Y. Wounds start the processes that can lead to decay.

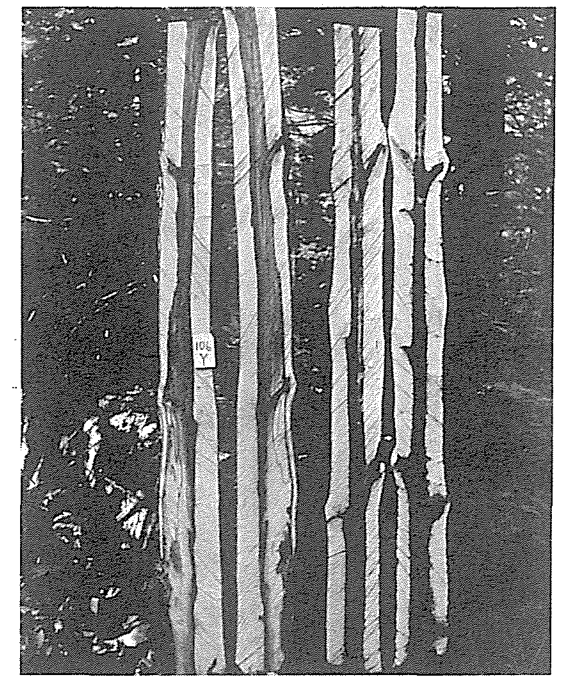

Fig. 2. Dissection of yellow birch tree 106Y. Decay at the base is associated with the 8-year-old wound. The central column of discolored wood above is associated with the dead branch stubs. The diameter of the column of discoloration was the diameter of the tree when the branches died.

At this early stage in the process, microorganisms are usually not involved in the discoloration process. These early discolorations of cell contents do not weaken the wood. The process initiated by the wound may stop at this point when the wound heals. Whether it heals or not depends on the severity of the wound, the time of year of wounding, and the vigor of the tree. Wound healing appears to be genetically regulated. Some trees heal wounds rapidly while others of the same species do not. In some trees the tissues surrounding the wound continue to die for several weeks, thus increasing the size of the wound.

When the wound does not heal rapidly, discoloration continues to develop. Then, in time, the cambium—that thin layer of tissue under the bark that produces new wood and bark each year—responds to the wound. If the wound occurs during the dormant period, the cambium responds to the wound as soon as growth begins again in the spring. If it occurs during the growing period, the cambium responds immediately.

The first cells produced by the cambium after a wounding are different from the cells that are normally produced. They have thicker walls, smaller vessels, more cells with protoplasm, and different orientation. These new and different cells act as a barrier to the discoloration process. They wall off the discolored wood; they compartmentalize the defect. The discoloration can spread up and down inside the tree, within the core sealed off by the barrier cells, but it does not spread outward into the new wood being formed.

The extent and intensity of discoloration depend on the vigor of the tree, the severity of the wound, and time. Discoloration continues to advance as long as the wound is open. If the wound heals, the entire cylinder of wood present when the tree was wounded may not become discolored. Meanwhile, the cambium continues to form new growth rings that are free of discoloration.

Microorganisms. At the same time, some of the microorganisms that first colonized the nutrient-rich wound surface may begin to grow into the tree. Many different microorganisms can be found on the wound surface—most common are fungi in the genera *Penicillium*, *Alternaria*, *Hormodendrum*, *Gliocladium*, and *Mucor*. They compete for nutrients, and many do not survive the intense competition. Of those that do survive, only a few types are able to begin growing into the wood through the wound—only those that can thrive in the discolored wood.

The first microorganisms to invade the tree—the pioneers—usually are bacteria and nondecay fungi. The most aggressive pioneer fungi are those in the genera *Phialophora*, *Fusarium*, *Cytospora*, *Ceratocystis*, *Graphium*, *Cephalosporium*, and *Gliocladium*. The principal pioneer bacteria are in the genera *Pseudomonas* and *Bacillus*. In some cases, decay fungi are pioneers. Some of the principal pioneer decay fungi are *Fomes annosus* and *Armillaria mellea*. The pioneers first infect the cells that have been altered by chemical changes in response to the wound. The new tissues formed after the injury still remain free of infection. The tree begins to compartmentalize the pioneer microorganisms.

The infected cells are further altered by the pioneer microorganisms. The discoloration may intensify; the cells may become moister; the mineral content of the cells may increase; and parts of the cell walls may be slightly eroded. Because of these changes, the infected wood in different species of trees is called by many names: "wetwood," "mineral stain," "blue butt," "brownheart," "redheart," "blackheart," and so on. It is not true heartwood. The wound-disease process can still stop at this stage if the tree is vigorous and the wound heals.

In some cases the wood tissues are killed, and decay microorganisms begin to move in. The succession of the microorganisms continues. The decay microorganisms affect those tissues that were altered first by chemical changes and then by the pioneer microorganisms. But still the new growth of wood that continues to form remains free of discoloration and decay.

The wound-disease process continues as long as the wound remains open. Many species of microorganisms may interact with one another until the dead wood is decomposed. The succession of organisms does not stop when the first decay microorganisms enter; it stops only when the tissues have been completely digested.

The decaying wood is often separated—walled off—from the new whitewood by a band of discolored wood. The pioneer microorganisms may remain in this band. As decay continues, the decay microorganisms slowly digest this disolored band; and only a hard, black rim then separates the (by then) hollow core from the healthy whitewood.

Up to this point the process may take 40 or 50 years or even longer. Healthy white blemish-free new wood will surround the hollow core, unless other wounds are inflicted later.

It is important to note that the processes need not go through to completion. Healing of wounds, antagonism among organisms, unfavorable environments, and other forces may cause the processes to abate in any stage.

Control of decay. Described above is a series of events that follow a single wound at one period in the life of a tree. But a tree is apt to be injured a number of times; and the same process takes place each time.

After a tree dies, or is cut down, a large mass of dead wood—cellulose and lignin—remains. Sometimes, materials impregnated in the walls of wood cells when they were still living make some kinds of wood very resistant to decay long after the tree is cut, and products are made from the wood. But under favorable conditions of moisture and temperature, microorganisms will begin to digest the dead cells in wood products and in cut timber.

As the decay process proceeds in wood products or cut timber, many species of microorganisms—a few at first and many later—grow into the wood; and slowly the wood is digested. Successions of microorganisms occur here also. Some preservative treatments will stall the decay process for a long time; but, given enough time and proper conditions, the microorganisms will succeed in digesting the wood.

In living trees decay can be prevented by avoiding wounds. In wood products and in cut timber, decay can be prevented by keeping moisture low or by using preservatives.

Wounds on living trees can be treated to minimize decay by cutting away dead bark, shaping the wound to form a vertical ellipse, pruning dead and dying branches, and watering and fertilizing to increase tree vigor. Results of recent research show that the commonly used wound dressings do little to stop decay.

The chances for regulating the decay process will increase as more is learned about host response to wounding and compartmentalization and about successions of microorganisms.

For background information *see* WOOD DECAY in the McGraw-Hill Encyclopedia of Science and Technology. [ALEX L. SHIGO]

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